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NOTES ON SOUTH AFRICAN CERCARIAE *

ERNEST CARROLL FAUST

During the last few years Capt. F. G. Cawston of the South African Medical Corps has published several articles on South African cercariae. But, as Cort (1919:488) has so aptly remarked, "his descriptions and figures of this [cercaria of *Schistosoma haematobium*] and other forked-tailed cercariae which he has described are so entirely inadequate that it seems to me that his entire work needs verification by more competent observers." The writer has made a careful analysis of slides and alcoholics of species which Cawston has sent to Professor Henry B. Ward and presents the data in this paper.

Cercaria gladii Cawston 1918 (Fig. 1)

This furcocercous cercaria, found in *Isidora schakoi* at Potchefstroom, Transvaal, is of striking interest because of its conspicuous tail, the forks of which are prolonged into long, sword-like processes. The larva measures 0.25 mm. in length by 0.073 mm. in width. The main portion of the tail is 0.29 mm. long, while the furci have a maximum length of 0.38 mm. The body is distinctly glandular and the tail is conspicuously muscular. The integument is entirely covered with minute spines. The oral sucker has a transverse diameter of 33 μ . The acetabulum lies about two-thirds the body distance from the anterior end. It is only 26 μ in diameter. The oral sucker opens into a short undivided gut without evidence of any pharynx. Cawston's Figure 3 (1918:69) is a very inadequate and inaccurate diagram of this cercaria. Heavy mucin ducts empty thru the ventral margin of the oral sucker, rather than farther anteriad, as in many furcocercariae. The openings are tipped with hollow piercing spines. Each of the two groups of ducts can be traced back to three large mucin glands, with relatively small nuclei and a network of granules in the cytoplasm. A mass of many germ cells is found near the posterior margin of the body. The central nervous system is unique in its position at the inner end of the gut. From it extend caudad two main ventral nerve trunks and delicate dorsals. No cyst granules have been found in the cercaria. It is quite unlikely that the larva encysts.

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Cawston has made no mention of the sporocyst of this species. Material which the writer has examined shows it to be muscular at the anterior end.

Cercaria secobii Cawston 1915 spec. inq.

Because of the poor mounts which have been available for study little can be added to Cawston's confusing description of *Cercaria secobii*. The data taken as a whole show clearly that this cercaria, first secured from *Physopsis africana* from the Umsindusi River, Pietermaritzburg, Natal, after the host had been subjected to an invasion of miracidia of *Schistosoma haematobium*, are not the cercariae of human bilharziosis. Cawston (1915: 257) states that "the evidence is not absolutely conclusive that these cercariae were present as a result of their exposure to infection of miracidia; but, in view of the recent work done by Leiper in Egypt, the inference is allowable." Such an inference is entirely without justification either from the experimental or the anatomical data.

Our actual knowledge of this species may be summed up in the statement that it is a furcocercous cercaria with a body about 150 by 24 μ , an undivided tail trunk 200 μ long and furci equally long, developing within a sporocyst, without pigment eye-spots and probably without pharynx. It is further distinguished from the cercaria of *Schistosoma haematobium* by a somewhat smaller, narrower body and by longer tail furci. The mucin gland ducts are probably the "divided gut" of Cawston's description. The really diagnostic features of number and character of mucin glands and ducts are altogether wanting.

Cercaria secobii is apparently confined to the coastal region where *Physopsis africana* abounds.

Cercaria parvocolata Cawston 1919 (Fig. 2)

This species, found in *Physopsis africana* at Durban, Natal, has a body measurement of 120 x 50 μ , a tail trunk 220 to 250 μ long, and furci about 100 μ long. Its oral sucker is pyriform. It possesses a small, weak acetabulum, and three pairs of acidophilic mucin glands with small nuclei. A clump of germ cells is found just posterior to the mucin glands. The pair of minute eye spots is found midway between the mucin glands and the base of the oral sucker.

A most remarkable fact in connection with *C. parvocolata* is the development of the cercariae in simple sacculate rediae, which are distinguished from the usual parthenitae of the group (sporocysts) by the presence of true pharynges and rhabdocoel ceca.

Cercaria of *Schistosoma haematobium* (Figs, 3, 4, 5)

These cercariae have been described and figured by Leiper for Egypt and by Cawston and others for Natal. For the former territory *Bullinus* spp. have been found to serve as hosts for the invading miracidia, while in Natal *Physopsis africana* is the mollusk involved. The life history of this species has been thoroly established by the brilliant work of Leiper. Unfortunately, this writer has almost entirely overlooked the anatomical features of the larvae. Only the grosser features have been included in his diagrams (Leiper, 1915). These are so general as to serve no purpose in the identification of the related larval schistosome species. While the shape and relative proportions of the body, tail trunk and furci are important, items of greater diagnostic value for furcocercous cercariae are the exact type of the digestive system, including number and type of mucin glands and ducts, the number of germ-gland cells, the nervous system, and the number and relation of flame cells and excretory tubules.

Specimens of this cercaria from Natal which the writer has studied have permitted an analysis of the digestive system, including the mucin glands and ducts, and the germ cells, together with the external body features. The body of the cercaria averages about 0.24 mm. in length by 0.1 mm. in width, while the tail trunk measures 0.2 mm. long by 47μ in diameter at the base. The small blunt furci are about half as long as the tail trunk. The large oral sucker gives the larva a decidedly robust appearance. The acetabulum is small and weak. Body and tail are covered with minute spines which are heavier and longer at the anterior end of the body. The oral sucker leads into a digestive tract without any evidence of pharynx. An esophagus runs backward into ceca which extend about three-fifths the distance caudad. Paired groups of mucin-gland ducts empty their slimy contents at the outer margin of the oral sucker. Each duct opens thru a hollow piercing spine which caps the duct (Fig. 5). Each group can be traced back to three mucin glands in the region of the acetabulum. These cells have loosely scattered granules in the cytoplasm and large nuclei. No other mucin glands have been found. Several germ cells have been found in the region of the body posterior to the acetabulum. The number is considerably in excess of the number of testes in the adult worm.

In specimens of the cercariae of *Schistosoma mansoni* from Caracas, Venezuela, which the writer has been enabled to examine thru the courtesy of Dr. Juan Iturbe, the mucin glands consist of only two pairs of cells of the granular type, but, in addition, four pairs of a non-granular type, somewhat smaller and surrounding the granular cells. The ducts are decidedly heavier than in the South African species. They open thru six spinose protuberances which cap the ducts.

To clear up Iturbe's work on this species it is necessary to state that the figure in Iturbe's paper (1917) is not a photomicrograph, but rather a diagram more nearly corresponding to the cercaria of *S. japonicum* than to the actual cercaria of *S. mansoni* which Iturbe found in the vicinity of Caracas.

Recently Cort (1919) has made a study of the cercaria of *S. japonicum*, which is altogether the most thorough anatomical analysis yet made of a human schistosome larva. The number of flame cells on each side of the body is four, rather than five as Miyairi and Suzuki found; likewise, the number of mucin gland cells is five for each side of the body, whereas the Japanese investigators considered the number to be three. As he says, the difficulty in differentiating the three human schistosome cercariae "is undoubtedly due to the limitations of our knowledge than to a lack of specific differences."

TABLE FOR DIAGNOSIS OF SPECIES OF HUMAN SCHISTOSOME CERCARIAE

	<i>S. haematobium</i>	<i>S. mansoni</i>	<i>S. japonicum</i>
Size:			
Body	240 x 100 μ	140 x 60 μ	100-210 x 66 μ
Tail trunk	200 x 47 μ	200 x 27 μ	150 x 20 μ
Furci	80-100 μ long	50 μ long	75 μ long
Oral sucker	60 μ in transection x 64 μ in length	30-34 μ in transec- tion x 30-34 μ in length	33 μ in transection x 54 μ in length
Mucin glands	3 pairs with large nuclei and gran- ular acidophilic cytoplasm	2 pairs with large nuclei and gran- ular acidophilic cytoplasm; 4 pairs with small nuclei and baso- philic slime con- tents	5 pairs with large nuclei and gran- ular acidophilic cytoplasm
Mucin ducts	Moderately thick	Very thick	Very thick
Duct openings	At anterior end of oral sucker; capped by 3 pairs of hollow pierc- ing spines	At anterior end of oral sucker; capped by 6 pairs of hollow, piercing spines	At anterior end of oral sucker; capped by 5 pairs of hollow, piercing spines
Germ cells	Several large cells posterior to ace- tabulum	Many cells at pos- terior end of body	Clustered mass of cells just behind acetabulum
Parthenita	Sporocyst	Sporocyst	Sporocyst

Neither in Cort's description nor his figures is the exact relationship of the piercing spines to the openings of the mucin gland ducts clear. While he may be correct in assuming that these glands "of the fork-tailed cercariae appear to be homologous to the stylet

glands of the xiphidio-cercariae which open at the base of the stylet or piercing organ, and to which the function of dissolving tissue in connection with the penetration of the cercaria into its host has been ascribed by certain authors," he is not exact in his statement that "instead of a single stylet as in the xiphidio-cercariae, the schistosome cercariae have a number of spines around the openings of the cephalic gland which perform the same function as the stylet in penetration." For each one of these piercing spines, hollowed in the center, caps the opening of a mucin gland duct, and it is thru this hollowed spine that the secretion of the gland is poured forth (Figs. 4, 5). This has been clearly demonstrated not only in the cercariae of *S. haematobium* and *S. mansoni* and in *Cercaria gladii*, but also in many undescribed schistosomes which the writer has studied, as well as the larval echinostome, *C. acanthostoma* Faust. The numbers of piercing spines for each mucin gland group is five in the cercaria of *S. japonicum*, altho Cort has figured five on one side of his drawing, and only four on the other side. This exact relation of a piercing spine to the opening of each duct has been borne out in every case which the writer has examined. Thus for *Cercaria gladii* and the cercaria of *S. haematobium* there are paired groups of three hollowed spines, while in the cercaria of *S. mansoni* there are six piercing spines to each group.

Cercaria catenata Cawston 1917 (Fig. 6)

Cawston's basis of diagnosis of this species which was found in *Planorbis pfefferi*, *Lymnaea natalensis* and *Physopsis africana* at Durban, Natal, was the "chain of blackish granules" which "lay on each side of the divided alimentary canal." Even with this apparent distinction Cawston has labelled certain specimens of *Cercaria catenata* "tadpole cercariae." A more thoro study shows the presence of a collar of spines just behind the oral sucker. This fact, among others of critical value, places the species among the larval Echinostomidae.

Contrary to Cawston's designation of the species as a large form (1917: 131), the writer has found it to be small, especially small for the group to which it belongs. The body measures 0.26 mm. in length by 0.13 mm. in width. The tail is 0.4 mm. long and only 36μ in diameter at the base. The oral sucker is 24μ in section, and the acetabulum 43μ . The latter is sunk in a deep circular depression which has a diameter about twice that of the acetabulum.

The oral sucker leads thru a very short prepharynx into a small pharynx. From the pharynx the esophagus, almost capillary in structure, runs posteriad to the anterior margin of the acetabular depression, where it gives rise to ceca of very small diameter. These end just behind the posterior margin of the depression.

The main tubules of the excretory system are characteristically echinostome. From the sides of the transversely compressed bladder two lateral collecting tubules run forward just outside of the ceca. They continue almost as far as the plane of the pharynx where they flex outward and backward. A single median tubule runs backward from the bladder thru the tail. It forks at the very end of that organ so that two outlets are formed. Cawston's "chain of blackish granules" refers to the granules in the excretory system.

The germ cells in the cercaria consist of a group of units in the median line posterior to the caudal margin of the acetabular depression and another mass on the anterior margin of the depression. These are connected by a chain of cells. The body of *Cercaria catenata* is crowded with cystogenous cells. The cyst granules in the cells are long narrow bodies closely packed together side by side. Judging from this provision, encystment must occur rapidly in this species.

Cawston has described the redia of *C. catenata* as a robust animal with four walking legs, a pointed posterior end, and a large gut filled with orange-colored material.

Cercaria constricta nov. spec. (Fig. 7)

Liver tissue of *Physopsis africana* which Cawston sent from Natal has been found to contain rediae and cercariae of a new larval echinostome for which the name *Cercaria constricta* is proposed. The body of the larva measures 0.19 mm. in length by 0.1 mm. in width, while the tail averages 0.28 mm. in length by about 40μ in section at the base. The entire body and tail are covered with very sharp spines directed posteriad. In the region lateral to the pharynx there is a deep constriction of the body which sets off the head from the trunk. A collar of sharp spines, larger than those covering the body as a whole, runs in a single series along the anterior margin of the constriction. It is complete except for a small gap on the ventral side just below the pharynx.

The acetabulum has a width measurement of 53μ and a length diameter of about 35μ . The oral sucker has an average diameter of about 35μ . The digestive tract consists of a short prepharynx, a small muscular pharynx, a long esophagus reaching to the anterior margin of the acetabulum, and furci which extend to the subcaudal region of the body. Mucin glands have been seen, but their arrangement in the body has not been exactly determined.

The excretory bladder is quadrangular in shape and quite muscular. From the median posterior margin a single caudal tubule runs half the distance distad, where it splits into two tubules. These tubules open laterad in the subdistal region of the tail. An anterior collecting

tubule from each of the anterior angles of the bladder runs forward to the plane of the pharynx, where it reflexes and continues backward. Further than that the writer has not been able to make out its course. The tubules contain no excretory granules.

Conspicuous germ-gland cells have been observed just anterior to the acetabulum.

The redia is an elongate sac without feet, with a minute obovate pharynx, a simple gut and a deep constriction in the region of the neck. A birthpore has not been observed. The redia is entirely covered with spines.

It will be noted that *Cercaria constricta* differs from *C. catenata* in several important points. Prominent among these are the spinosity of the cercaria and redia of *C. constricta* and lack of such integumentary differentiation in *C. catenata*; difference in type of excretory tubule in tail, and absence in *C. constricta* of the circular depression found around the acetabulum of *C. catenata*. The lack of excretory granules in *C. constricta* is probably of specific value, but this point needs checking with living material. A further distinction between the two species is found in the presence of four feet in the redia of *C. catenata*, while the redia of *C. constricta* lacks feet entirely.

That *Cercaria arcuata*, described by Cawston (1918a:95) from the Transvaal, is still a different species of larval echinostome is shown from the fact that the species has two redial feet, and an anterior collecting system which empties thru a single median stem into the bladder.

Cercaria arcuata Cawston 1918 (Fig. 8)

The original description of this species was made by Cawston on the material from *Isidora* sp. from the Schoonpoort at Klerksdorp; the material which the writer has had an opportunity to examine is from *Lymnaea natalensis* from Natal. As in other echinostome larvae which Cawston has described, he has referred to this species as a "leptocercous cercaria" (1918a:95).

The body of *Cercaria arcuata* is 0.15 mm. long by 0.1 mm. wide in the region of the acetabulum. The tail is about one and one-half the length of the body. The body is entirely covered with spines which are most conspicuous at the anterior end. A distinct collar prominence has been seen on the worm, but no collar spines have been made out with certainty. The anterior end of the body is capable of considerable extension. The oral sucker measures 37μ in diameter, and the acetabulum has a diameter of 33μ .

The redia is a long sac with a pair of pointed feet about in the middle of the body. At the anterior end of the body pharynx, collar prominence and birth pore can be readily seen. The rhabdocoel gut

may be small or large, depending on the age of the redia and the amount of food ingested.

Contrary to Cawston's description, the writer has been able to make out a prominent pharynx just dorsal to the oral sucker. It leads into a long esophagus. The furci arise just anterior to the acetabulum and continue nearly to the posterior limit of the body.

The excretory bladder is an elongate median organ extending nearly to the posterior margin of the acetabulum. Here it forks in horse-shoe fashion to form two dilated collecting tubules which run forward to the region of the pharynx. It is filled with a few very large excretory granules, the "chain of cystogenous vesicles" of Cawston. The finer portions of the collecting tubules have not been made out. The collecting tubule in the tail forks soon after it enters that organ. The two branches continue distad and open to the exterior in the subdistal region of the organ.

The body is filled with an enormous amount of cystogenous granules, which obscure all the finer structure of the worm. On encystment these granules are extruded from the body, forming a covering around the decaudated worm.

Cercaria cawstoni nov. spec. (Fig. 9)

This is one of the "tadpole cercariae" which Cawston has recorded for *Physopsis africana* and *Lymnaea natalensis* from Natal. A comparison of the figure accompanying this description with Cawston's several figures of this type shows how entirely inadequate and misleading his description is.

The larva is ovate-oblong, with a slight protrusion at the oral end and an impocketing at the posterior end into which the tail fits. The body measures 0.38 mm. in length by 0.21 mm. in width. The tail measures 0.31 mm. in length by 43μ diameter at the base. The body is entirely covered with minute spines, but the tail is aspinose. At each side of the caudal pocket is a studded cluster of long, heavy spines, which are imbedded in a thickened region of the integument (Fig. 9, 9 b). The oral sucker has a diameter of 43μ , while the acetabulum measures about 60μ . Imbedded in the dorsal wall of the oral sucker is a stylet, 27μ long. This organ is of the simple quill type, but is unique in having a median longitudinal reinforcement in addition to the usual transverse thickening (Fig. 9 a).

From the oral sucker the digestive track is traced thru a short prepharynx to a minute pharynx, 16μ in diameter. From this region a short esophagus leads to the ceca which extend nearly to the posterior end of the body. Emptying at the sides of the stylet are paired groups of mucin gland ducts, each group arising from four mucin

cells. These cells have large vacuolated nuclei and a homogeneous chromophilic cytoplasm. The excretory bladder is a transversely constricted organ into which empties a common collecting tubule. This tubule forks just posterior to the acetabulum. A single mass of germ cells has been found posterior to the acetabulum.

The body of *Cercaria cawstoni* is filled with cystogenous granules. When the cercaria is freed from the ruptured sporocyst it drops its tail and encysts.

Cercaria frondosa Cawston 1918 (Fig. 10)

Cercaria frondosa is a sturdy amphistome larva measuring 0.4 mm. in length by 0.31 mm. in width, with a tail 0.43 mm. long by 57μ in section at the base. The oral sucker has an average diameter of 66μ , while the acetabulum, 95μ in diameter, is situated at the posterior margin of the body and not on the ventral side as Cawston has figured it (1918:69). The parthenita is a large, heavily walled muscular redia, varying in size, but always possessing a prominent pharynx, a long, slender gut and a birth pore. The worm was found in *Isidora schakoi* at Potchefstroom, Transvaal.

Internally, the oral sucker leads into a cavity with distinct pharyngeal pockets, which probably argues for its place among the Diplodiscinae. The short esophagus is not surrounded by a postpharyngeal sphincter. It opens into a rather inconspicuous pair of ceca which run posteriad to the region of the acetabulum. The bladder is small, but collecting tubules which empty into it from the side, are enormously dilated by excretory granules. The two main tubules can be traced forward to a region under the pigment areas immediately behind the eye-spots. A single tube, running thru the middle of the tail, forks near the proximal end of that organ to open thru small pores to the exterior. The germ cells of the cercaria consist of a clump of elements in the median line just behind the anterior limit of the lateral excretory tubules.

Two eye-spots are present. They are of a bee-hive shape, with the pigment cup opening anterolaterad. The optic cell is conspicuous in the young cercaria long before the pigment granules accumulate around it. Spreading out from the eyes in frondose arrangement are pigment elements which show under high magnification a grouping into flaky masses that at times extend over the entire dorsal surface of the animal.

Large rhabditiform cystogenous granules pack the parenchyma cells of the cercaria. Upon the maturing of the cercaria either within the liver gland of the snail or after wandering out of the host, the cystogenous granules are thrown out to form a heavy cyst membrane

With encystment the tail is dropped and the larva passively awaits transmission to the subsequent host. Cawston has called this larva a leptocercous distome.

Cercaria fulvoculata Cawston 1919 (Fig. 11)

Cawston called this species leptocercous, but it must be placed among the larval monostomes. It is ovate in outline, with slight auricular prominences on each side near the anterior end. The body is 0.4 mm. long and half as wide. The tail is heavy and about 0.6 mm. long. It is provided with six paired groups of long falciform cells surrounding the caudal excretory canal. The body has a small but prominent oral sucker and a pair of aspinose caudal pockets. The cercaria is binocular, with flecks of pigment surrounding the eye spots and at times extending backward along the nerve tracts. The cercaria was taken from *Lymnaea natalensis* at Durban.

A large bladder lies mesad near the posterior end of the body, with lateral conduits opening into it from the sides. These ducts connect with one another just posterior to the eyes. In front of the bladder is an ovarian cell mass, and ventral to the cornua of the bladder are small testicular germ masses. Ducts from these glands run forward in parallel courses to the region of the genital pore, which is situated behind the plane of the eye spots.

The redia is a simple sacculate structure with medium-sized pharynx and long slim gut. There are no feet. A birth pore has not been seen.

DISCUSSION

A survey of the data above shows the inadequacy of Cawston's descriptions. In a private communication he has stated that the illustrations are most unsatisfactory, but are very similar to those of Drs. Leiper and Atkinson in the *British Medical Journal*. This is no less unfortunate. It is true that Leiper's descriptions and figures will not serve to separate species of larval schistosomes, because all details of structure are omitted. Leiper's statement (1915: 39) that the systematic position of a bifid-tailed cercaria can only be effectively established in the first instance by experimental infection of a susceptible host and the subsequent examination of the adult resulting therefrom is misleading and entirely out of accord with the facts. Specificity of structure is as characteristic of the larval fluke as of the adult, and failure to find specific differences between cercariae is due to inadequate observation.

These difficulties are generally felt, and Leiper (1918: 168) states that there is no evidence that the various forms so loosely and repeatedly termed "*Bilharzia cercariae*" in Cawston's numerous papers

EXPLANATION OF PLATE

Fig. 1.—*Cercaria gladii*, ventral view, showing digestive, nervous and reproductive systems. $\times 170$.

Fig. 2.—*Cercaria parvoculata*, ventral view of body only, showing digestive and germ-cell glands. $\times 330$.

Fig. 3.—*Cercaria* of *Schistosoma haematobium*, ventral view, showing digestive glands and germ cells. $\times 170$.

Figs. 4 and 5.—Anterior tip of cercaria of *Schistosoma mansoni*. 4, mucin ducts and openings at anterior margin of sucker; $\times 330$. 5, tips of ducts, showing hollow spine capping each duct. $\times 990$.

Fig. 6.—*Cercaria catenata*, ventral view, showing digestive and excretory systems and germ cells. $\times 170$.

Fig. 7.—*Cercaria constricta*, ventral view, showing digestive and excretory systems. $\times 170$.

Fig. 8.—*Cercaria arcuata*, ventral view, showing digestive and excretory systems. $\times 170$.

Fig. 9.—*Cercaria cawstoni*, showing digestive and excretory systems and single mass of germ cells; *a*, stylet, enlarged; *b*, lateral view of cluster of caudal pocket spines, enlarged. $\times 170$.

Fig. 10.—*Cercaria frondosa*, ventral view, showing pigmentation around eye-spots, digestive and excretory systems and single mass of germ cells. $\times 170$.

Fig. 11.—*Cercaria fulvoculata*, ventral view, showing pigmentation around eye-spots, excretory and reproductive systems. $\times 170$.

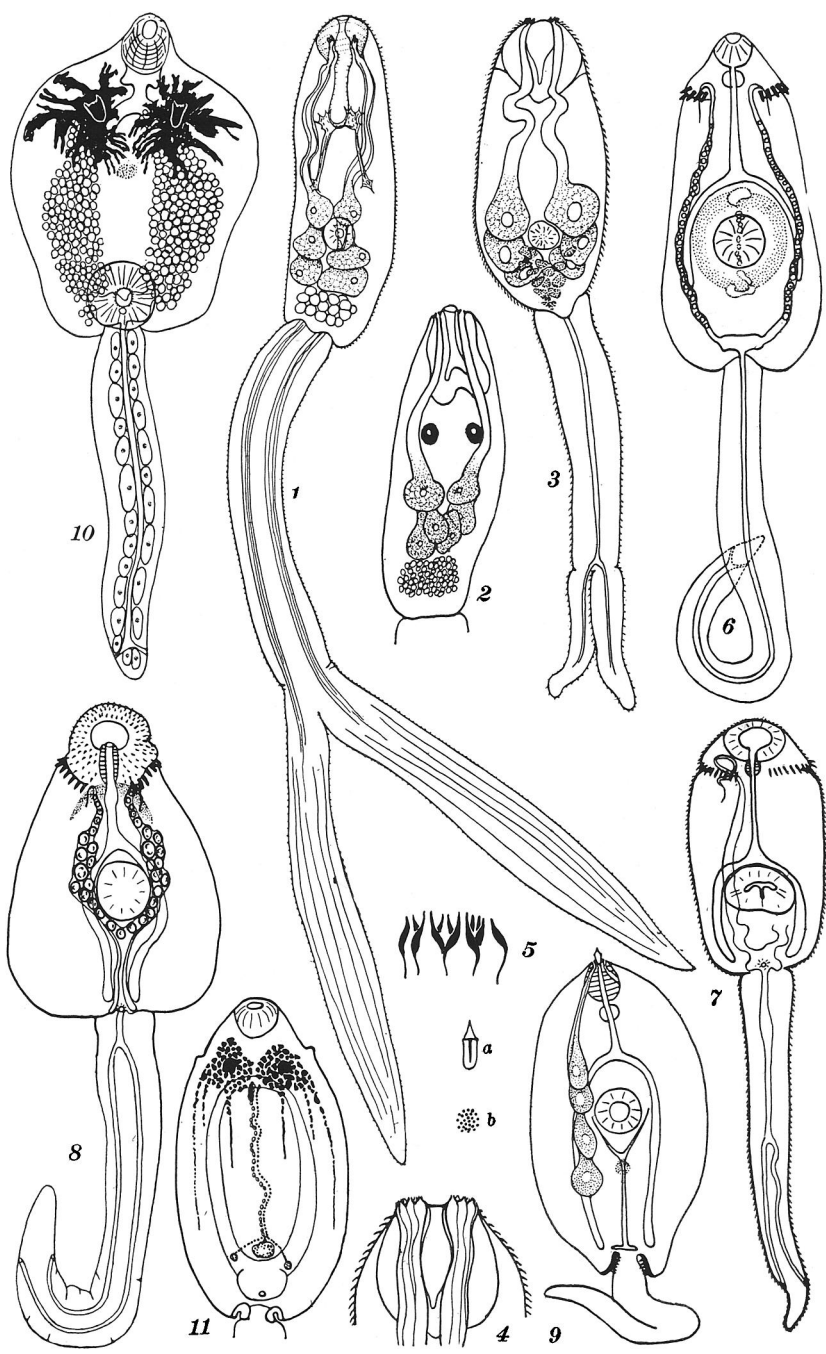


PLATE XVIII

are actually such. In a review of one of Cawston's papers (1916: 348) new figures are substituted for those in the original article (1915: 258). A comparison fails to show a single common likeness between any two of the figures, altho they are labelled "bilharzia cercariae." In another paper Cawston (1916a: 201) has labelled at least three distinct species (Cercaria of *S. haematobium*, *C. oculata* and *C. catenata*) as "human forms of Cercariae," altho the latter forms cannot possibly be considered human forms.

SUMMARY

1. Ten species of cercariae from South Africa, including two new, are described.

2. The cercariae of *Schistosoma haematobium*, *S. mansoni* and *S. japonicum* are easily distinguished on the basis of number and type of mucin glands and ducts, and their outlets. Differences in arrangement of the germ cells may also be used in this diagnosis.

3. Diagnosis of a larval trematode requires exact data on the size and shape, on the integument, on the excretory system, on the digestive system and on the germ cells.

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